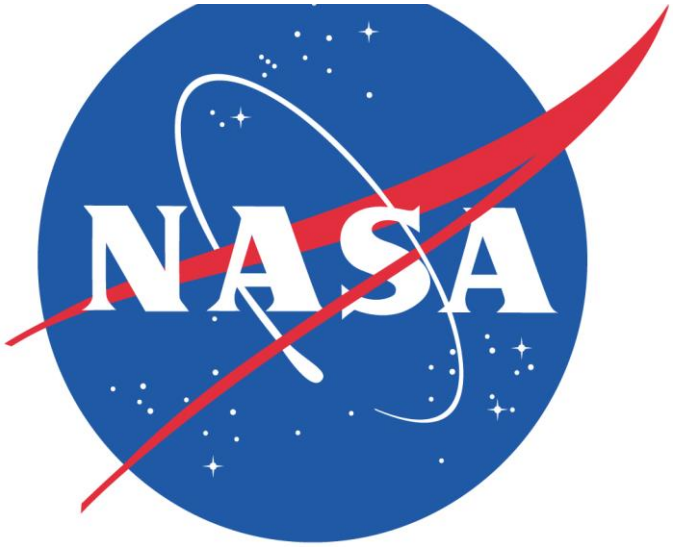


Particle Energy Calibration of Timepix Detector

Martin Kroupa

NASA Active Radiation Sensor Requirements

- Timepix selected to be the main technology used for future exploration missions' radiation monitoring (NASA dedicated to use technology next 10 – 20 years)
- Accurate, reliable dosimetry of energetic electrons, protons, and higher-Z ions
- Accurate, reliable measurement of energetic particle flux
- Accurate, reliable measurement of LET spectra (dE/dx)
  - Requires accurate measurement of both dE and dx

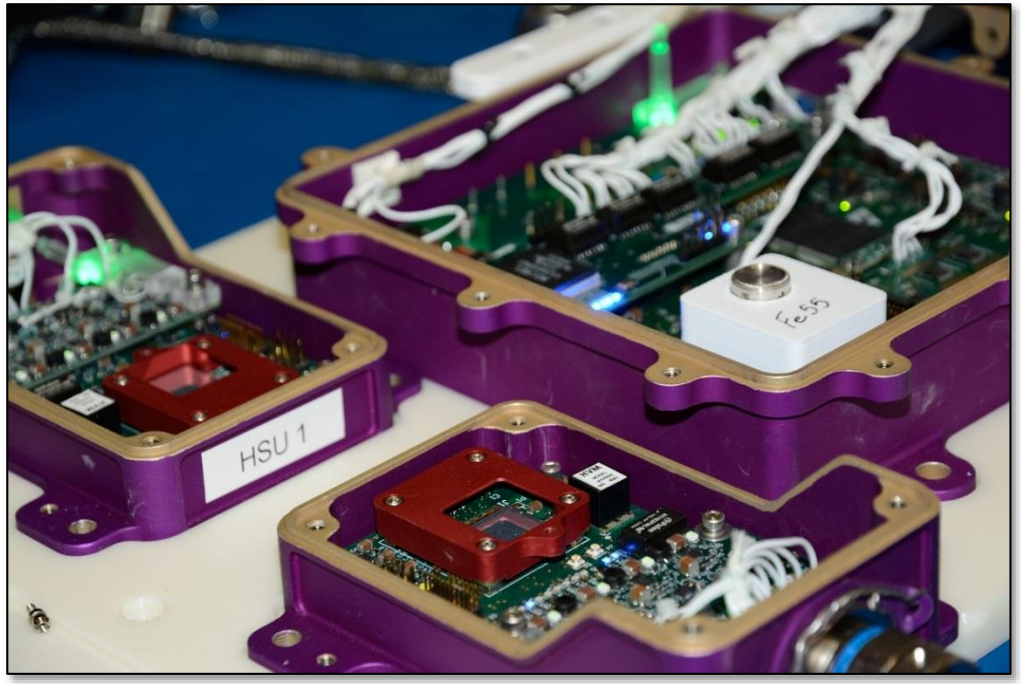
NASA/JSC Team and Efforts Using Timepix Technology

- REM TEAM

Quite a strong team – 4 HW developers (S. Wheeler), 5 SW developers (N. Townsend), mechanical, thermal engineers

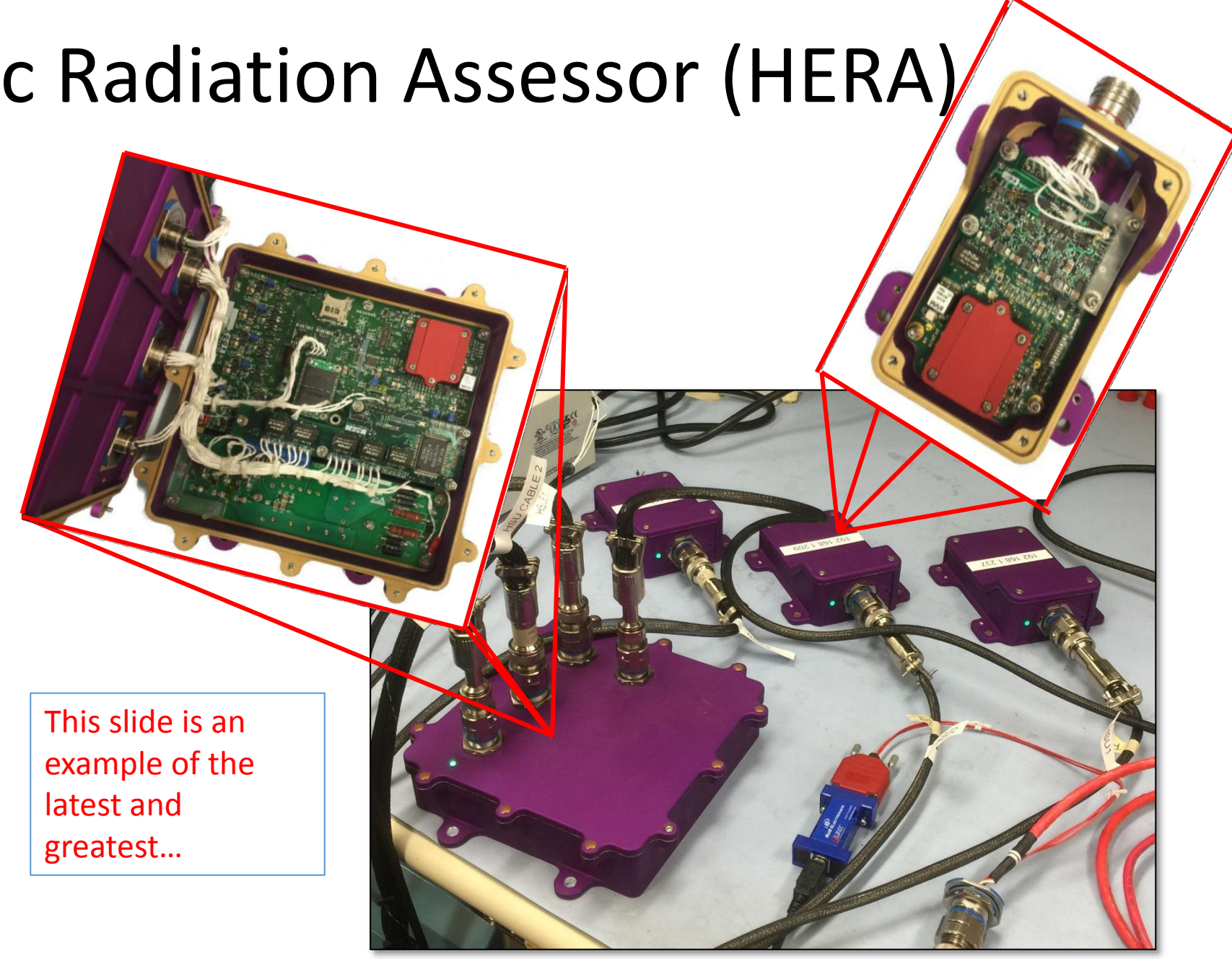
Science team - T. Campbell-Ricketts, A. Empl, A. Firan, D. Fry, R. Gaza, S. George, M. Kroupa, L. Pinsky, R. Rios, E. Semones, N. Stoffle

- Development Efforts
  - REM
  - BIRD
  - HERA
  - MPT
- Fast prototyping with off-shell products, following by own development
- Incremental capability



Hybrid Electronic Radiation Assessor (HERA)

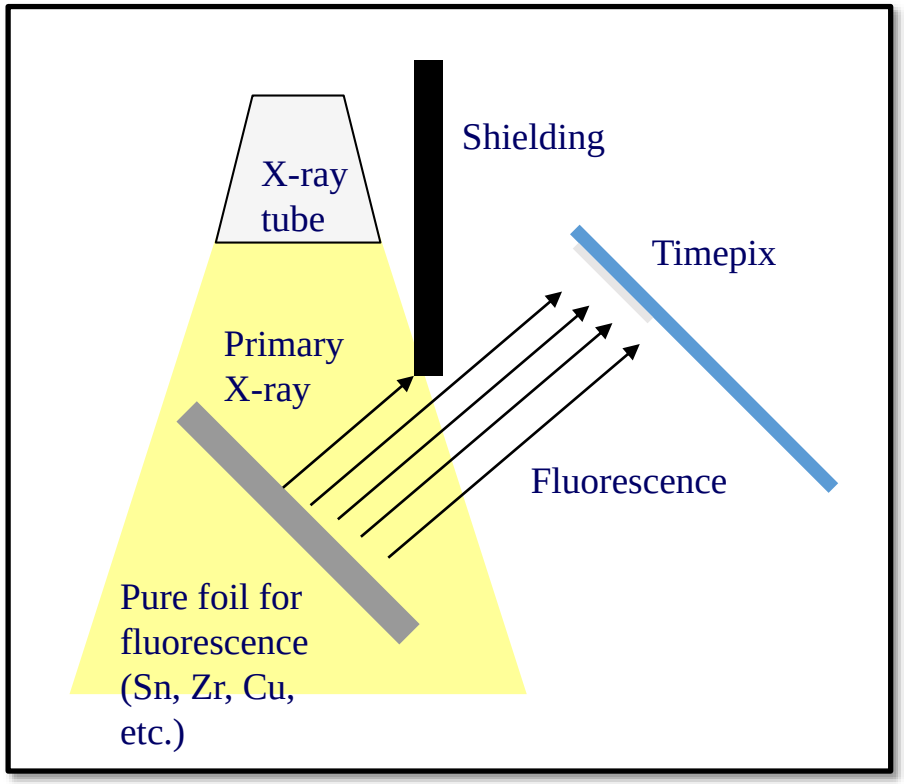
- Active dosimetry system built for NASA Multi-Purpose Crew Vehicle, based on semiconductor pixel detector technology (Timepix)
- Modular structure
- Completely stand alone capability, all data processing on board, including alarms, etc.
- Measures dose rates at up to four positions
- Gives estimate of the radiation environment
- dE/dx measurement, directionality measurement

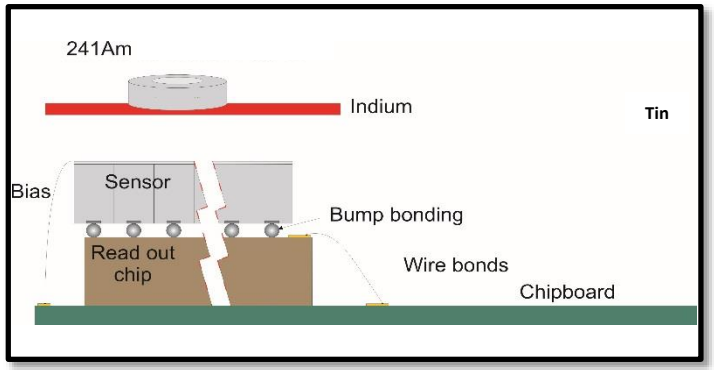


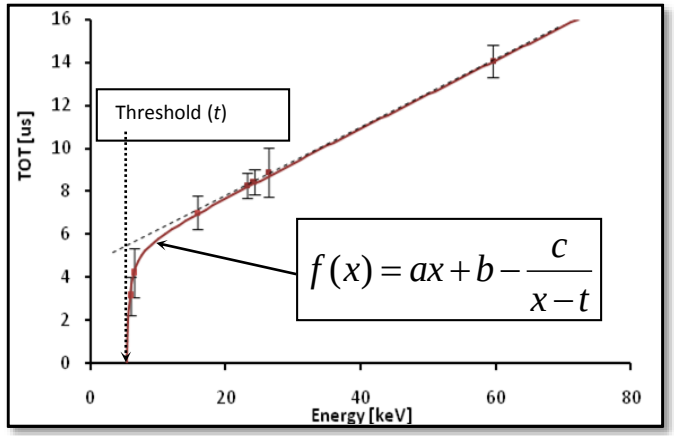
This slide is an example of the latest and greatest…

Energy Calibration

- A calibration laboratory was constructed at JSC
- The task is to calibrate more than 65k of multichannel analyzers
- Threshold set to 5 keV
- Measure spectrum in each pixel while occupancy is low → no pile up
- Measure for at least 3 points on calibration curve
  - 59.54 keV line from ^{241}Am
  - 25.27 keV fluorescence line from Sn
  - 5.99 keV from ^{55}Fe
- Note: calibration is using photons and thus not clear what a deposited energy in pixel is during calibration (charge sharing effects) → **need of advanced calibration**

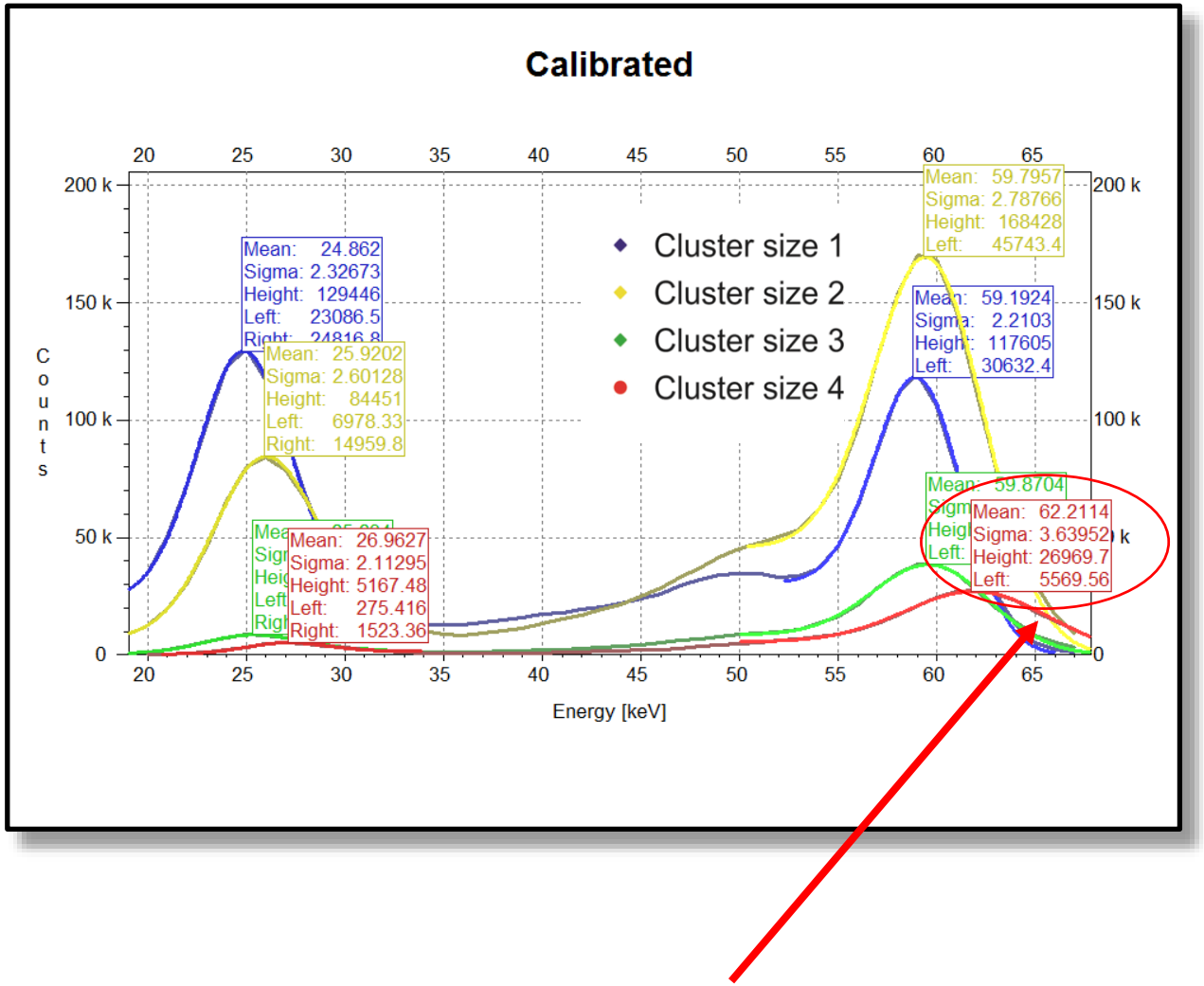






Energy Calibration

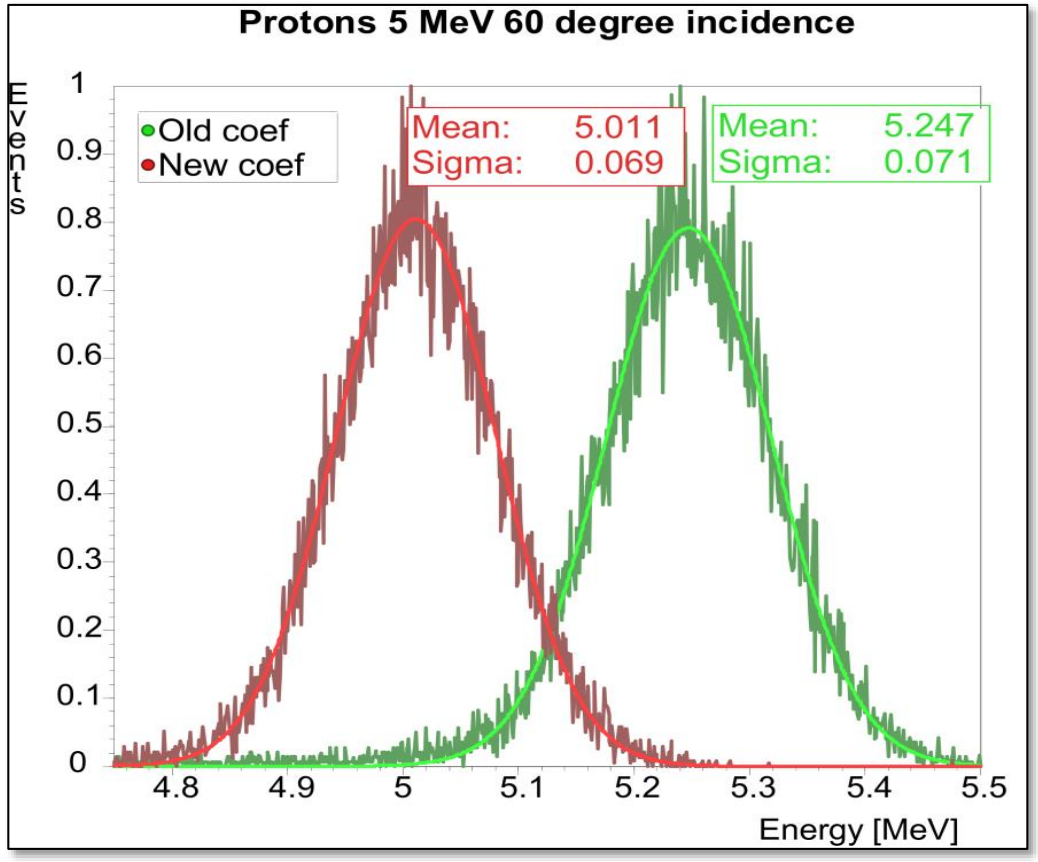
- Due to the detection processes and charge sharing effects the signal from one particle is often detected by several adjacent pixels creating a cluster
- Part of the signal might be lost under threshold
- The complete charge deposited by a particle can then be obtained by summing the signals from all pixels in a given cluster
- Regular calibration shows systematic error caused by difference between incident and measured spectra



Measuring 62 keV for 59.5 keV incident photon

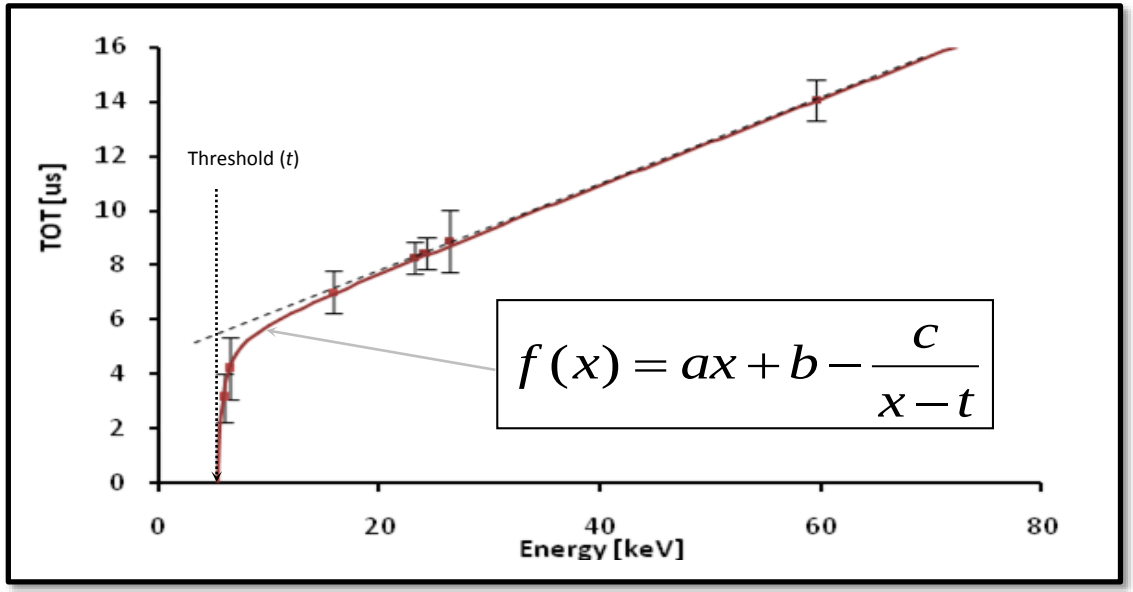
dE

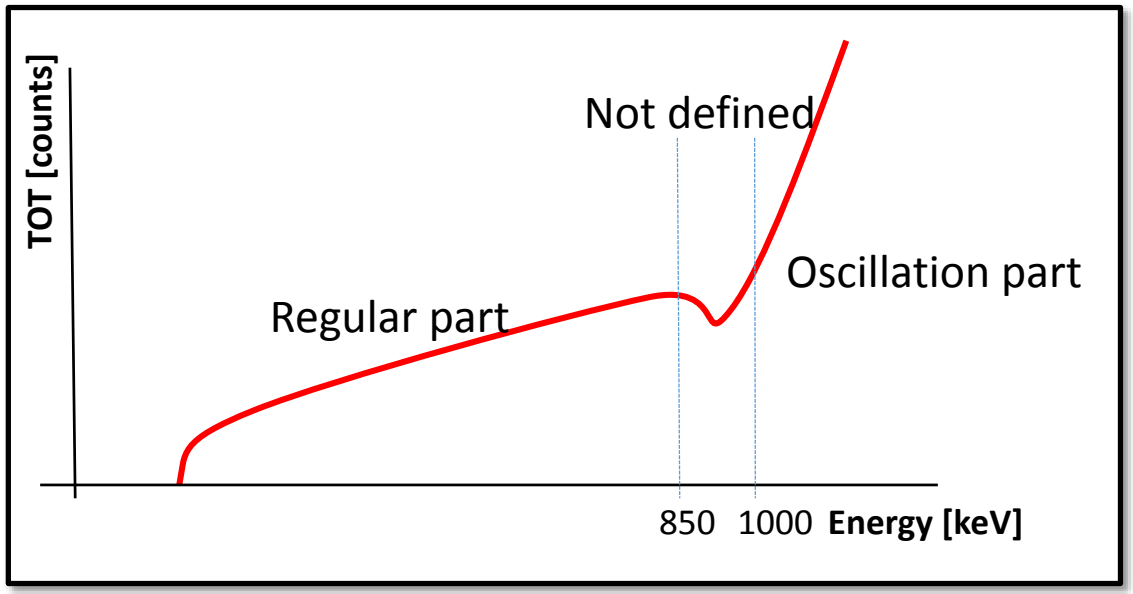
- Using data from TDVG, we were able to correct for charge sharing and verify if our estimated energy deposition from calibration was correct (guess method and simulation)
- New energies for calibration (Fe – 5.998 keV -> 5.58 keV, Sn – 25.27 keV -> 23.56, 59.54 keV -> 56.71 keV) – 500 µm sensor
- Verified by TDVG data where we know exact energy deposited



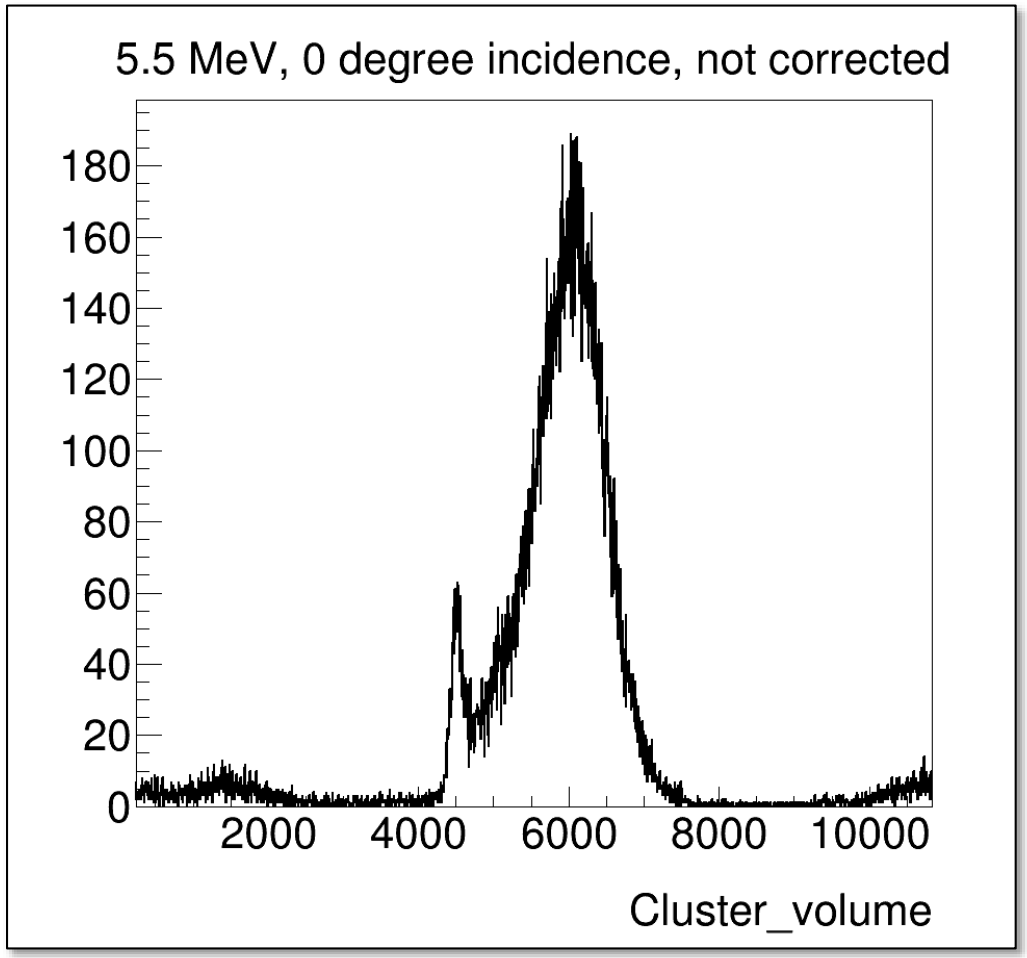
dE, (continued)

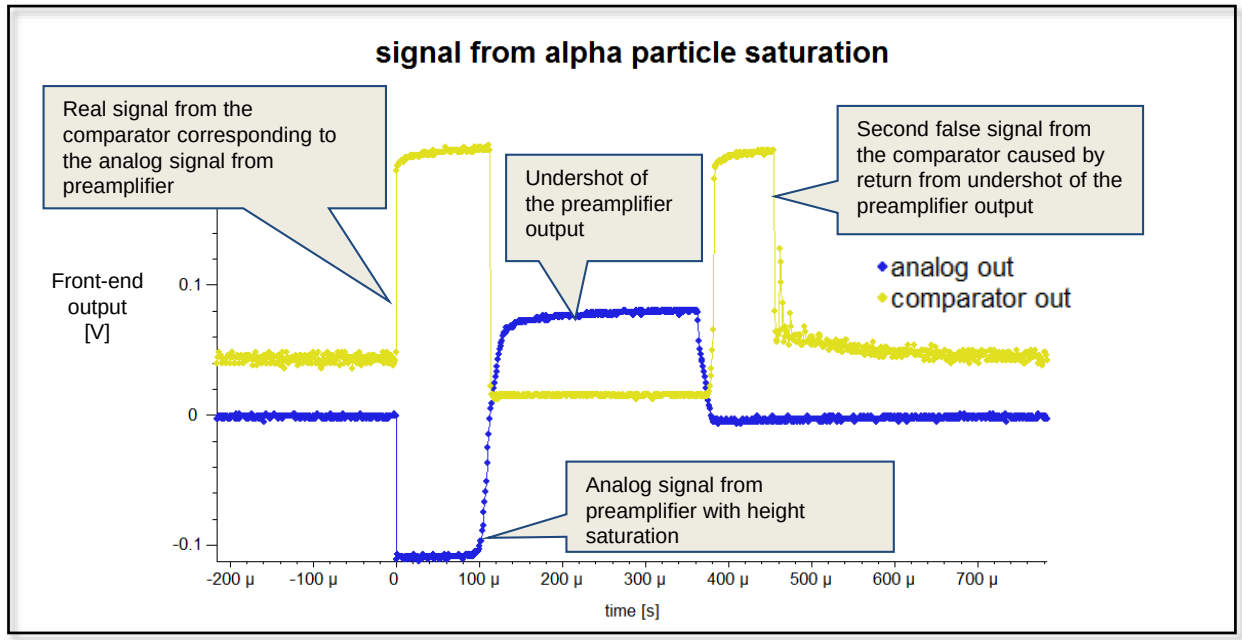
- Calibration function measured for each pixel
- Calibration curve more complex than thought
- Not defined for energies around 900 keV





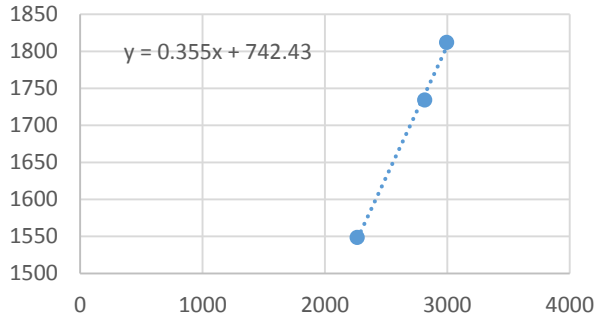
“Saturation”



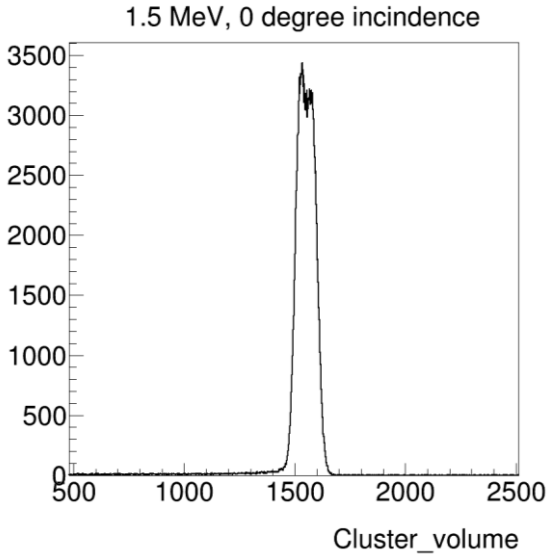


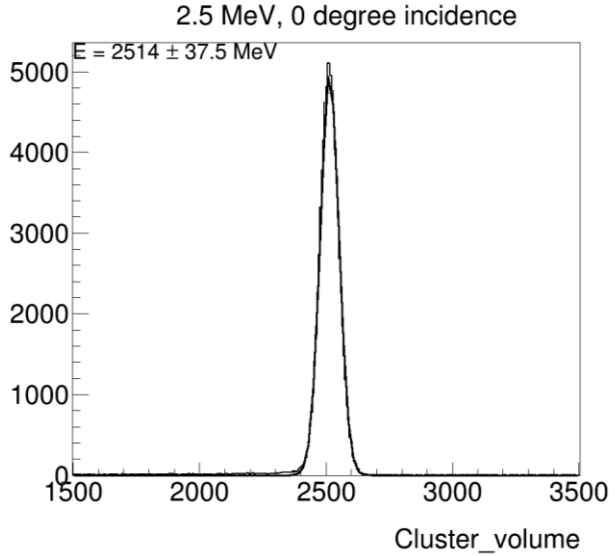
Angle	Volume	Height	Nominal	Difference	Real height
0	6180.4	2995.3	4997	1183.4	1811.9
10	6079	2816	4997	1082	1734
20	5713.3	2264.7	4997	716.3	1548.4
30					
40					
50					
60	4997	717.6	4997	0	717.6

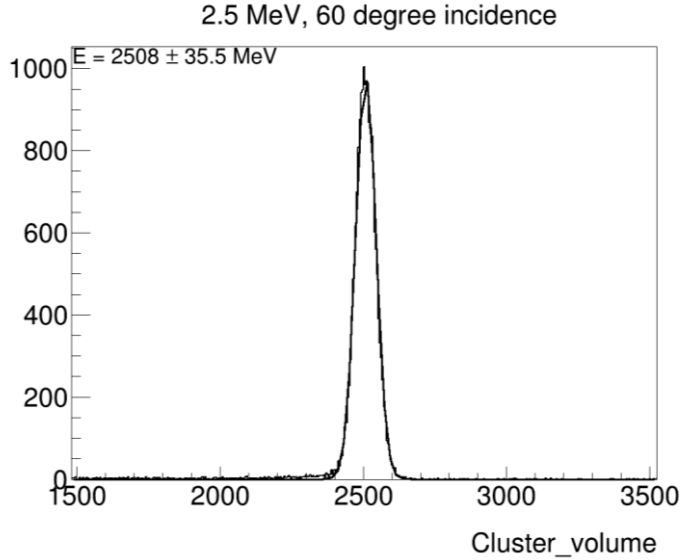
Corrected using data from stopping particles. Results in a new calibration curve applied if the energy in pixel is higher than 850 keV.

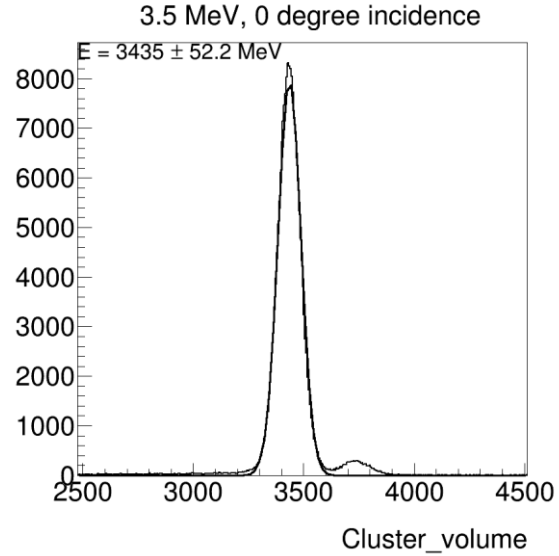


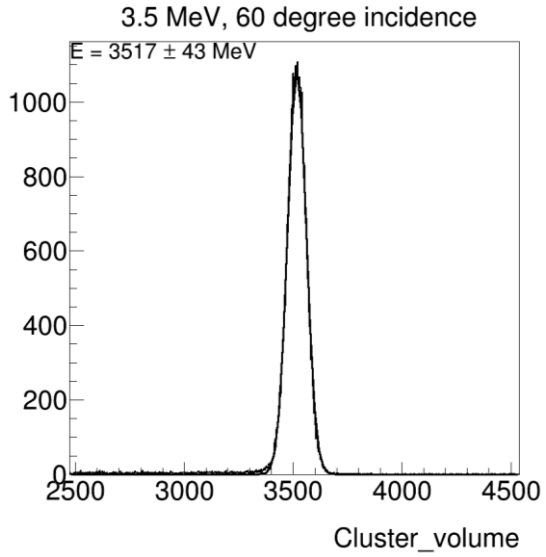
Verification of the Method

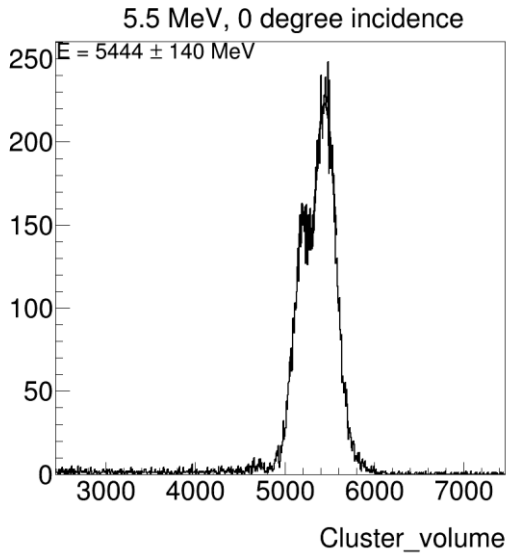


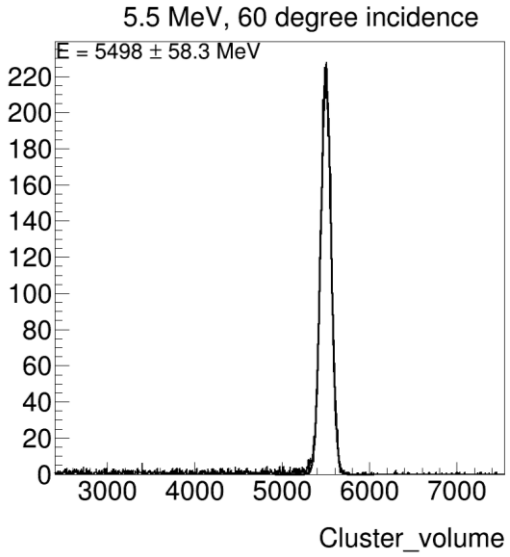


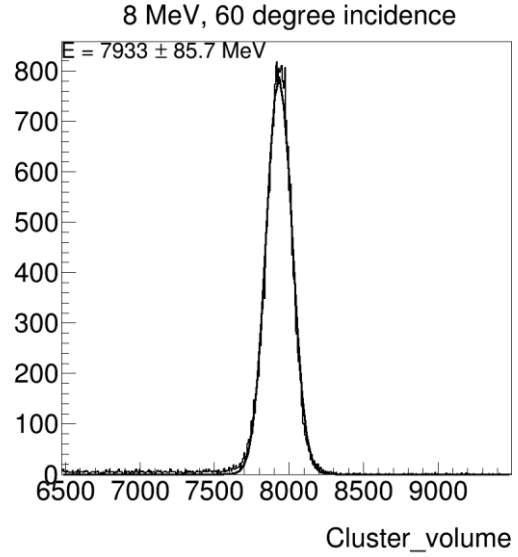












Verification of the Method

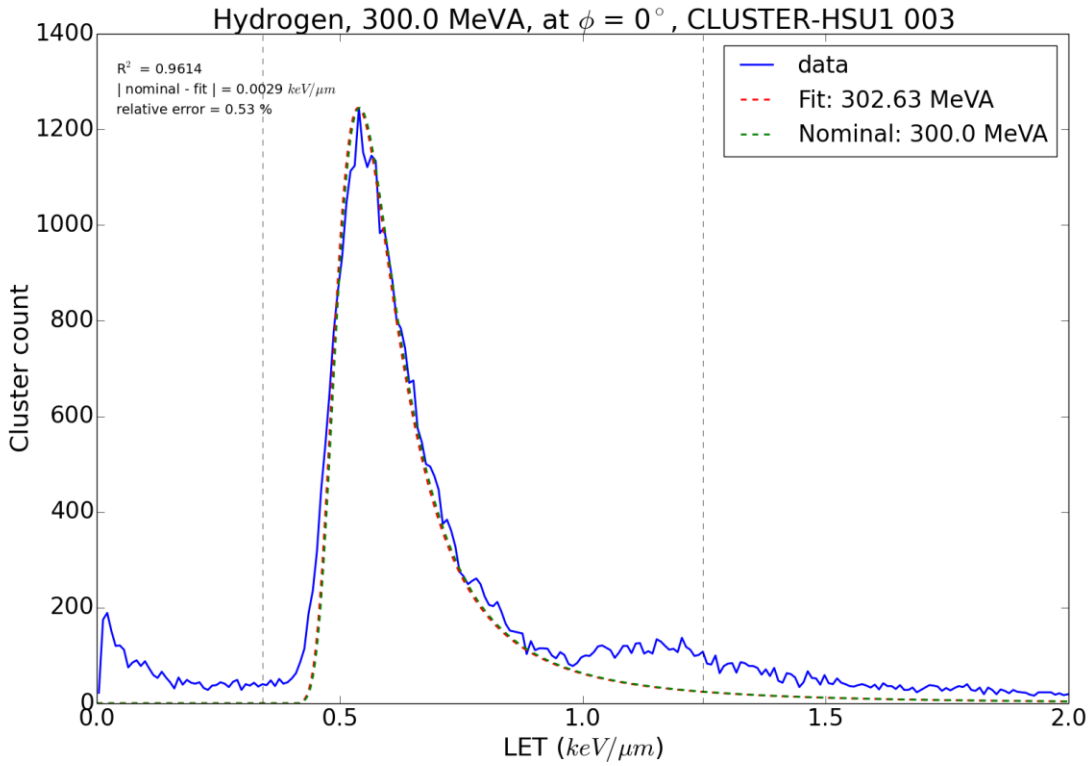
Tested on penetrating and stopping particles from protons to neon. Error reduced in some cases by 90%.

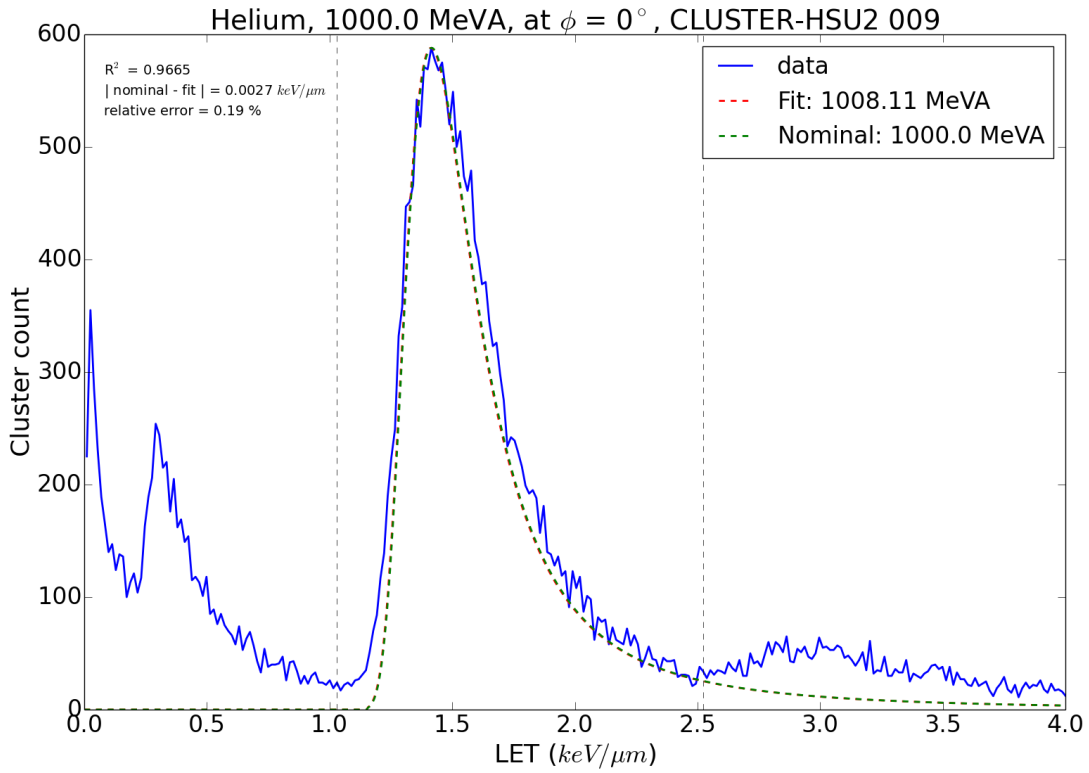
Primary	True energy (MeV/A)	Uncorrected Fit (MeVA)	Corrected Fit (MeVA)	Uncorrected Cluster Height (keV)	Error uncorrected %	Error corrected %
H	480	424.3	478.1	213	-11.6	-0.4
H	180	155.7	168.3	370	-13.5	-6.5
He	400	372.8	416.9	789	-6.8	4.2
He	207.8	197.9	207.9	846	-4.8	0.0
He	113.5	61.6	105.9	933	-45.7	-6.7
H	28	25.4	27.4	1049	-9.3	-2.1
C	180	105.2	174.3	4415	-41.6	-3.2
O	430	200.4	418.9	4500	-53.4	-2.6
Ne	498.4	225.6	543.9	4546	-54.7	9.1

Primary	True energy (MeV/A)	Uncorrected Fit (MeVA)	Corrected Fit (MeVA)	Uncorrected Cluster Height (keV)	Error uncorrected %	Error corrected %
H	5	5.2	5.0	2272	4.0	0.0
Li	10	12	9.7	2683	20.0	-3.0
Li	12	15.6	11.8	3125	30.0	-1.7

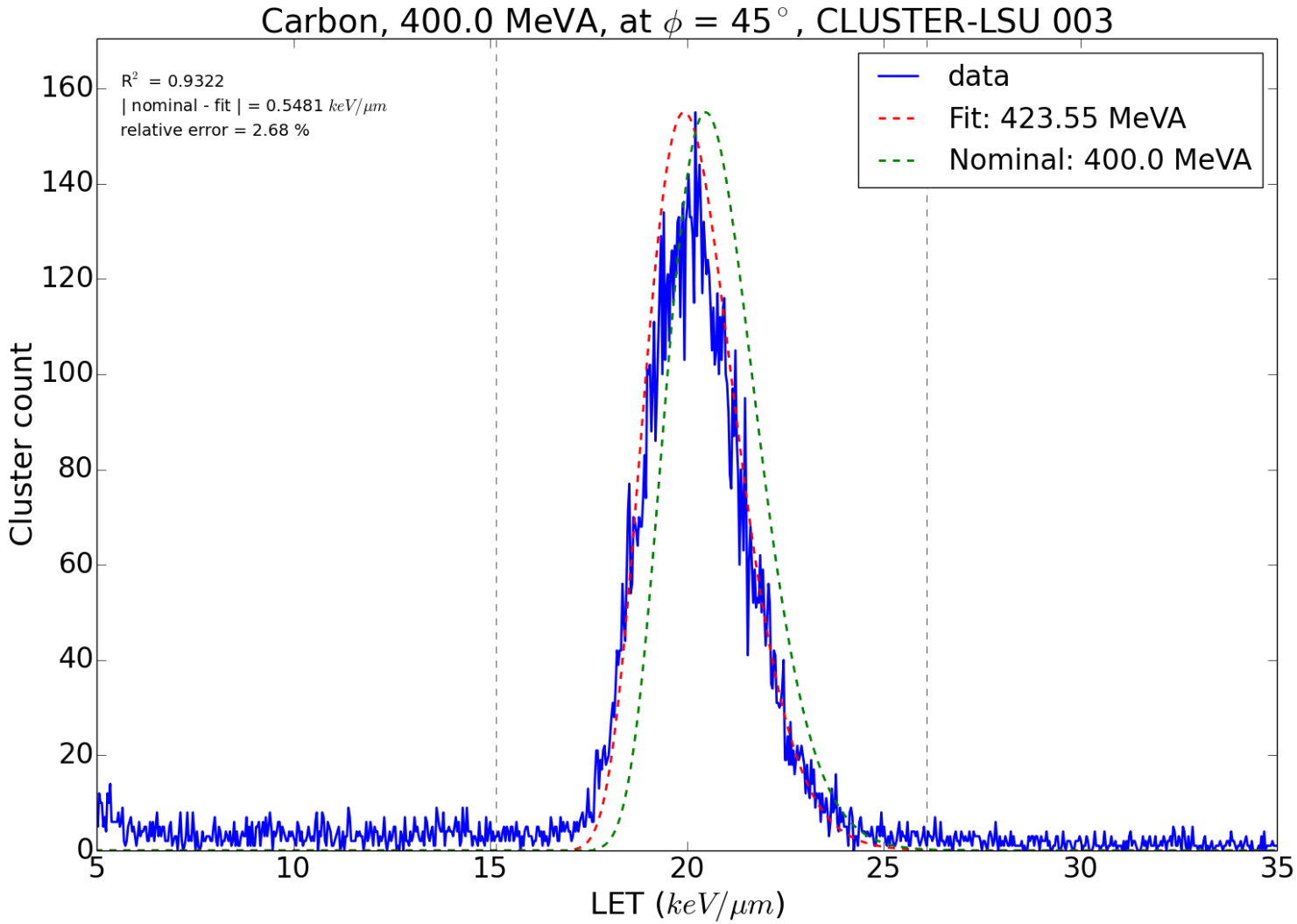
dx

- Using fuzzy logic to calculate polar angle and track length, which corresponds to dx
- Found some issues for parallel tracks – resolved, going to more complex algorithm



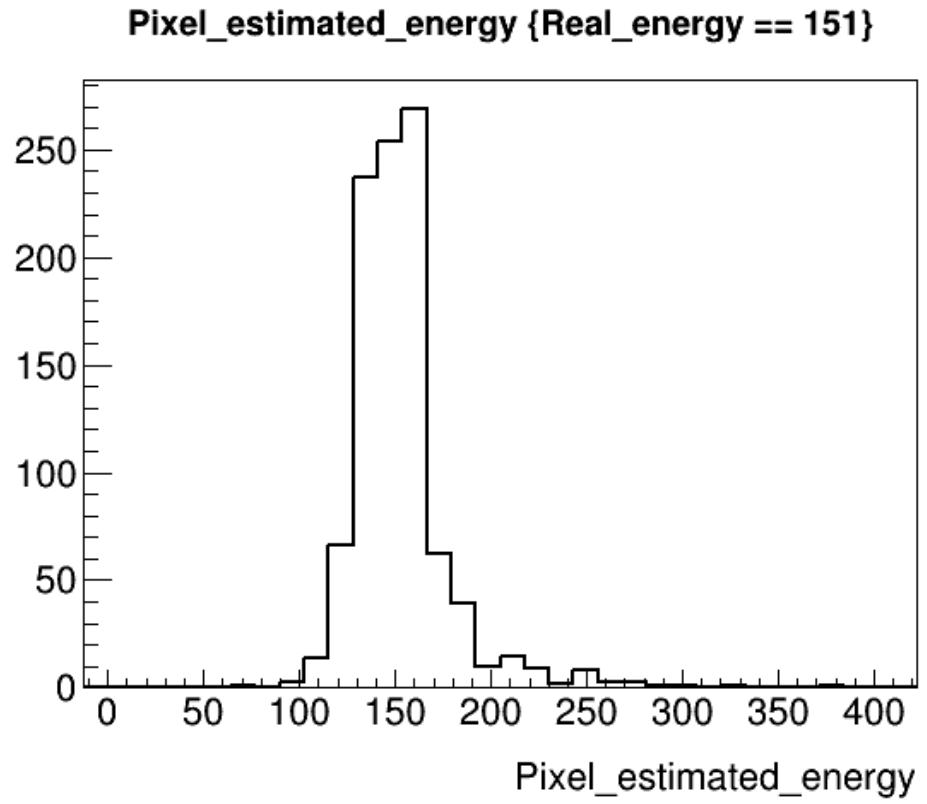


dx


Carbon, 400.0 MeVA, at ϕ = 45°, CLUSTER-LSU 003
R² = 0.9322
| nominal - fit | = 0.5481 $keV/\mu m$
relative error = 2.68 %
data
Fit: 423.55 MeVA
Nominal: 400.0 MeVA
Cluster count
LET ($keV/\mu m$)
0
20
40
60
80
100
120
140
160
5
10
15
20
25
30
35

Real Utility: Energy Reconstruction

- Want to use dE/dx measurements for particle ID and energy reconstruction
- Ongoing effort; first results will be published soon



Conclusions

- NASA has very well defined application for Timepix, will continue to work with it
- We are interested in the new chip development, improvements on front-end, TOA, low-power mode
- We plan to continue work on energy calibration (volcano effect) and evaluation procedures (thermal studies), simulations (Fluka and Geant4 models), eager to see TPX2
- We publish results of our work and plan to present more on MPX meeting (TPX3 study, advanced calibration, etc.)